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ABSTRACT

The document is a student resource unit to be used in teaching high school vocational agriculture students about air. The following natural processes are described: carbon dioxide cycle, nitrogen cycle, gravity and atmosphere, energy of the sun, greenhouse effect, atmospheric circulation, and precipitation. Sources of air pollution are discussed. Air pollution's damage to human and animal health, esthetics and visibility, climate, vegetation, and other things are treated. A section covers control of air pollution by industry, government, individuals, and agriculture. The report concludes with fifteen recommendations taken from "Environmental Quality: The First Annual Report of the Council on Environmental Quality." There is a 26-item bibliography. (MS)

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Ag Ed Environmental Education Series

AIR

WASHINGTON STATE UNIVERSITY IN COOPERATION WITH THE COORDINATING COUNCIL FOR OCCUPATIONAL EDUCATION.

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AgEd

Environmental Education Series

- Air
- Agricultural Chemicals and Radiation
- Animals
- Land Use
- Noise
- Plants
- Understanding the Environment
- Water

ED 084423

AIR

A student resource unit to be used in teaching high school vocational agriculture students about air.

by

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FOREWORD

This publication is the product of a project carried on by the Coordinating Council for Occupational Education and the Department of Education, Washington State University.

The project grew out of a recognition of the need to include as a part of the high school vocational agriculture curriculum information dealing with the environment, particularly as it relates to agriculture. The project was preceded by a period of growing concern that a body of factual information and teacher resources needed to be developed in this area.

E. M. Webb, Associate Professor of Agricuultural Education emeritus, first suggested that steps be taken to make available to teachers of agriculture and their students factual information on the environment and agriculture. It was through the efforts of Jay Wood, Program Director, Agricultural Education, Olympia, that a project was prepared and approved beginning in September 1970.

Valuable assistance was given the project by many persons from the following agencies: Washington State University, University of Washington, Western Washington State College, Soil Conservation Service, United States Department of Agriculture, United States Department of the Interior, Washington Parks and Recreation Department, Washington Department of Ecology, Washington Department of Natural Resources, Washington Department of Agriculture, Washington Department of Fisheries, Washington Water Pollution Control Commission, Environmental Protection Agency, and Washington Department of Game. Many other agencies provided information for the project.

Three publications were extremely useful in preparing this unit. They were *Environmental Quality: The First Annual Report of the Council on Environmental Quality*, *Environmental Quality: The Second Annual Report of the Council on Environmental Quality*, and *Wastes in Relation to Agriculture and Forestry*. Information from these publications was used as a basis for much of this unit.

Grateful acknowledgment is hereby made to the following groups of people:

Dr. C. O. Loreen and Dr. Keith E. Fiscus, both teacher-educators and state supervisors in agricultural education, and Mr. Jay M. Wood, program director, agricultural education, who gave able assistance to this endeavor.

Mr. Richard Rightmire and Mr. Patrick Alleyn, teachers of agricultural education in Washington high schools, reviewed the unit, developed teaching materials to be used with the unit, and taught the unit to their students. Many other teachers also made valuable contributions to the project.

The following subject matter specialists reviewed the unit: Mr. Gerald O. Freeman, Office of Technical Services, Division of Environmental Monitoring, Department of Ecology, State of Washington; Mr. Frederick L. Monroe, assistant chemical engineer, Research Division, Air Pollution Section, College of Engineering, Washington State University.

This unit is one of eight being produced under the project. The other seven include: *Understanding the Environment*, *Water*, *Noise*, *Agricultural Chemicals and Radiation*, *Animals*, *Plants*, and *Land Use*.

July 1972

Rodney W. Tulloch

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INTRODUCTION

President Richard M. Nixon's message to the Congress in August 1970, included the following statement:

> In dealing with the environment we must learn not how to master nature, but how to master ourselves, our institutions, and our technology. We must achieve a new awareness of our dependence on our surroundings and of the natural systems which support all life, but awareness must be coupled with a full realization of our enormous capability to alter these surroundings. Nowhere is this capability greater than in the United States, and this country must lead the way in showing that our human and technological resources can be devoted to a better life and an improved environment for ourselves and our inheritors on this planet.

It should be remembered while studying this unit on air that this is only one small part of ecology. Ecology is the study of interrelationships between living organisms and their surroundings.

This unit covers mostly present-day problems of an environmental nature. However, air pollution is not a new phenomenon. It has been a problem since near the beginning of the Industrial Revolution. Some persons living in previous generations have endured severe conditions of air pollution that would not be tolerated today. Nineteenth century citizen groups in London protested vigorously against the smoke-filled air. Their efforts were largely unsuccessful against the increase in air pollution that resulted from greater industrial development.

Air pollution was also becoming a problem in the United States toward the end of the 19th century. Chicago and Cincinnati passed smoke control laws in 1881. From that time through the early 1900's many other cities passed smoke control laws, but these had little effect. During the 1930's through the 1950's, air pollution became a serious problem. Public awareness and unwillingness to live with these conditions resulted in the enactment of legislation to control pollution from smoke. Coupled with improved enforcement, an improvement in visibility took place in some industrial cities.

The new controls were primarily aimed at cutting down smoke from fossil fuels, particularly coal. Diesel engines replaced the steam locomotives that had burned coal. Increasing amounts of gas were used for space heating, thus reducing the amount of coal burned for this purpose.

Until the middle of the 19th century, air pollution had been a phenomenon that occurred mostly in the East and Midwest. There the major causes of air pollution were fossil fuels, especially coal. In Los Angeles, where citizens have been complaining about worsening smog, virtually none of the fuels responsible for the smoke problems in the East and Midwest are used. Eventually it was discovered that the bulk of the smog in Los Angeles was due to photochemical oxidants produced by the action of sunlight on the hydrocarbons and nitrogen oxides found in automobile exhaust.

Complex air pollution problems are now confronting major cities throughout the world. Factors that cause urban areas to have serious air pollution include higher population density, industrial growth, and high numbers of motor vehicles. The wide-ranging effects of such factors have only been noted by the public in recent years because air pollution becomes noticeable when the capacity of the air to handle pollutants is overburdened. Many people consider air pollution to be a relatively recent development. A lack of understanding of the causes and effects of air pollution still exists among large numbers of people in the United States.

NATURAL PROCESSES

Air is a mixture of invisible gases. Small particles of water are sometimes present in air as are particles of solid materials such as dust. These water particles and dust particles are not part of the air but are carried by the air. Nitrogen makes up approximately 78% of dry air by volume. Oxygen amounts to nearly 21% of dry air by volume. The other 1% of the air is made up of argon and carbon dioxide; however, this ratio may vary somewhat due to location. For example, near sea level the percentage of some of these elements may be different than at much higher elevations. Near large cities where large numbers of automobiles are operated, carbon dioxide may increase. The amount of water vapor or dust carried by the air may also fluctuate greatly with location and the density of the air.

Carbon Dioxide Cycle

The carbon dioxide cycle is an important natural process. Photosynthesis is the process by which green plants manufacture their food. In photosynthesis, plants, in the presence of sunlight, remove carbon dioxide from the air and discharge oxygen. A fairly delicate balance exists between living things and the gases of the air. Photosynthesis contributes to this balance by taking carbon dioxide out of the air and putting oxygen back. Since a buildup of carbon dioxide has become a problem around some cities, it has been suggested that more green plants need to be grown in these areas. Since most animals take oxygen from the air and put carbon dioxide back, these two functions can be used to balance each other.

Nitrogen Cycle

The nitrogen cycle is an even more complicated process. Nitrogen-fixing bacteria remove nitrogen from the atmosphere. Plants that are members of the legume family, such as beans, peas, clover, and alfalfa, remove nitrogen from the air when nitrogen-fixing bacteria are present on the roots, since these bacteria are necessary for this process, legume-family seeds are often innoculated with nitrogen-fixing bacteria when planted in soil that has not recently had plants of this particular family. The innoculation process then ensures that the legume plant will take nitrogen from the air (see figs. 1 and 2).

After these plants take nitrogen from the air, they convert it into other nitrogen compounds that are vital to plant growth. When the plants are eaten or decay, the nitrogen and its compounds are released. Some of this nitrogen is released into the air.

Gravity and the Atmosphere

The earth's gravitational force largely prevents the molecules of gases that make up the atmosphere from diffusing into outer space since gas molecules tend to have little attraction for each other. This gravitational force holds over half of the weight of the earth's atmospheric gases within 3-1/2 miles of the earth's surface. The other half of the earth's atmosphere spreads upward for hundreds of miles. Since the gravitational force decreases as you move away from the earth, the atmosphere is held more loosely and thus becomes thinner at higher altitudes (see fig. 3).

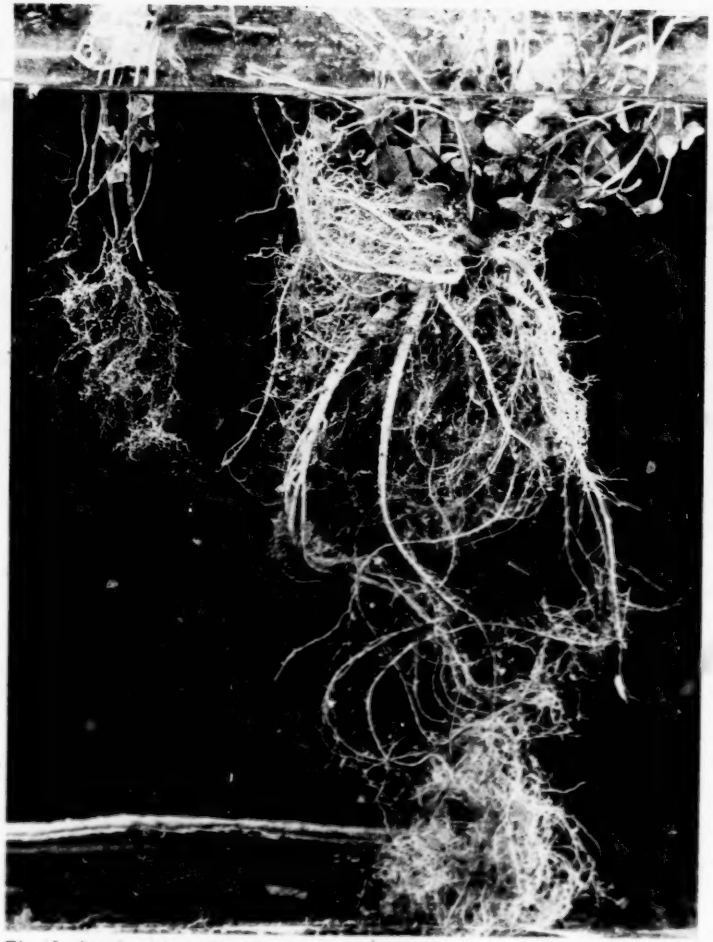


Fig. 1 A parasitic or ineffectual strain of bacteria invaded the plants on the left; numerous small nodules formed but fixed no nitrogen. The large plant on the right was properly inoculated with a high nitrogen-fixing strain of bacteria.

USDA Photo

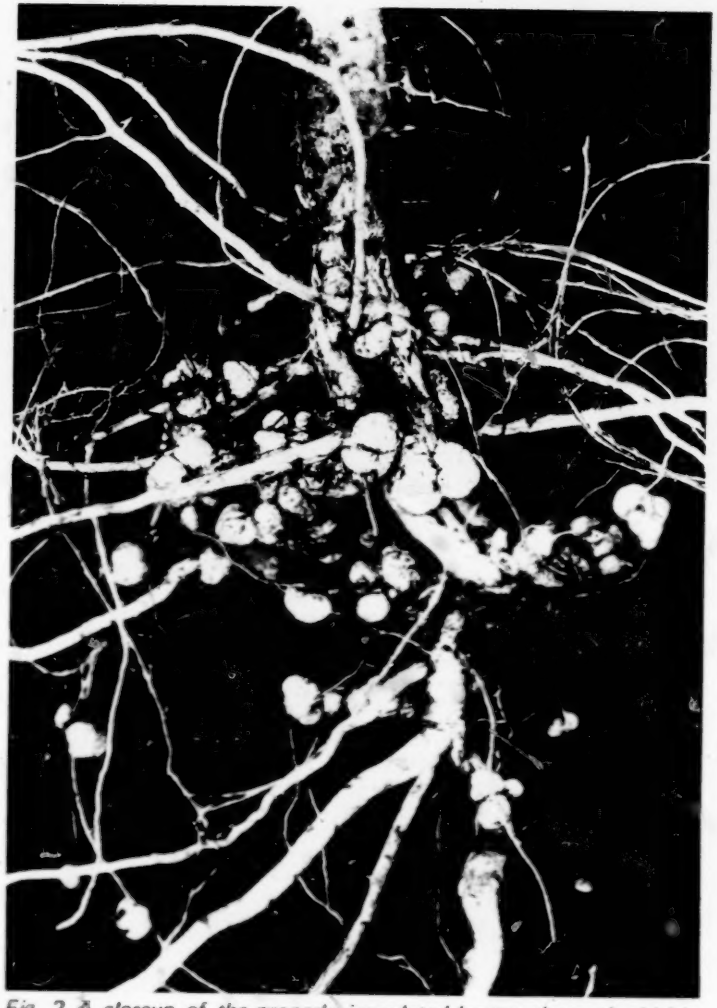


Fig. 2 A closeup of the properly inoculated legume shows the highly developed nodules on the roots.

USDA Photo

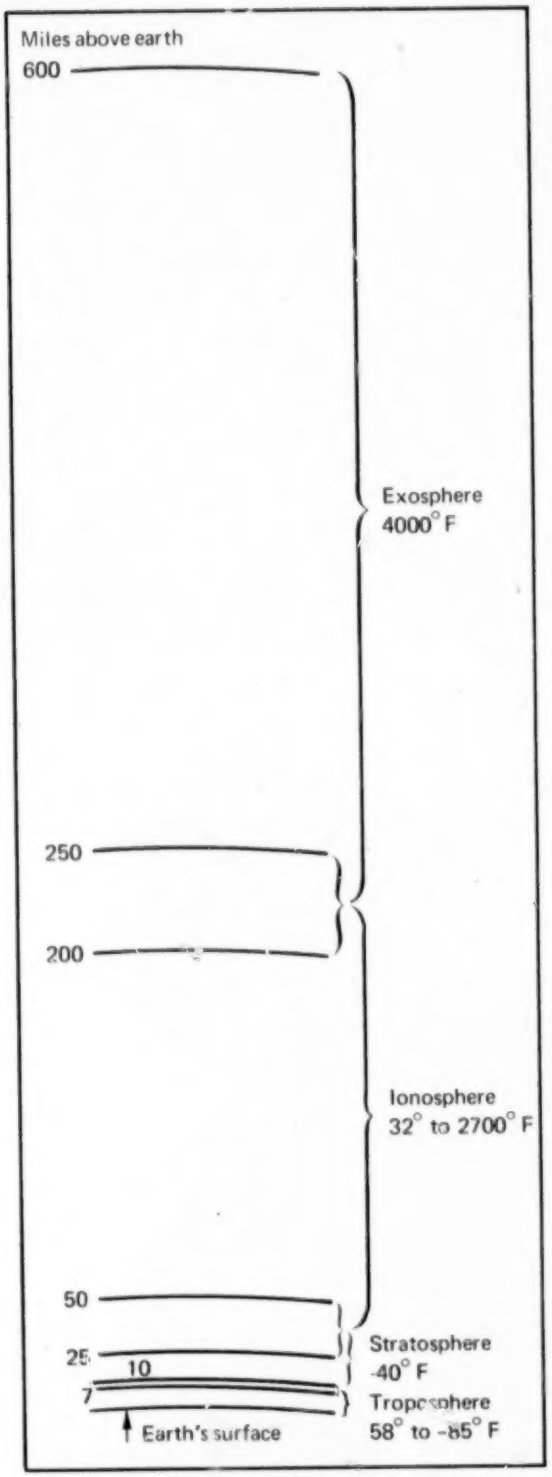


Fig. 3' Layers of the earth's atmosphere.

The earth's atmosphere is divided into four layers. The zone closest to the earth's surface is called the troposphere. It is in this 7- to 10-mile-thick layer that almost all weather activity takes place. The stratosphere starts at the upper reaches of the troposphere and extends up to 25- to 50 miles above the earth's surface.

Above the stratosphere is the ionosphere. The ionosphere contains electrically charged atoms known as ions. Ions are produced in the ionosphere because of the ultraviolet rays from the sun. These powerful ultraviolet rays from the sun split the atoms of the gas molecules. High concentrations of ozone are found in the lower levels of the ionosphere. Ozone is a very active form of oxygen that absorbs more solar radiation than other gases of the atmosphere. Ultraviolet radiation from the sun also raises the temperature of the ionosphere to several thousand degrees Fahrenheit, but the air in the ionosphere is so thin that objects passing through it would not be warmed.

The fourth zone of the atmosphere, the exosphere, extends from approximately 200 to 600 miles above the earth. Some of the particles from the exosphere actually escape the earth's gravity and drift outward into space.

Energy of the Sun

Slightly more than half of the total energy radiating from the sun toward the earth actually reaches the surface of the earth. Waves of energy (radiant energy) radiated from the sun may be reflected, refracted (bent), or diffused (scattered). Clouds in the atmosphere reflect nearly 35% of the sun's energy back into space. Approximately 10% of the sun's energy is absorbed in the upper zones of the atmosphere. The ozone layer of the ionosphere absorbs a particularly large part of this 10%. A large proportion of the

ultraviolet rays is removed from the upper zones of the atmosphere. It is fortunate for man and animals on earth that these ultraviolet rays are removed since they would quickly burn anyone exposed to their full effect for any period of time. The small number of ultraviolet rays that do reach the earth cause sunburn.

Greenhouse Effect

The greenhouse effect (fig. 4) is due almost entirely to trapped radiation which raises the temperature of the air. A little heat is added to the earth's atmosphere by conduction. However, air is a poor conductor, so little heat is added to the atmosphere in this manner. Adding to the greenhouse effect is the fact that moist air in clouds reflects the heat radiated from the earth back toward the earth. This is the reason that cloudy nights tend to be warmer than nights when the skies are clearer.

As an air pocket is heated it tends to become less dense and rise if it is in cooler, more moist, and denser air. On a sunny day, energy from the sun is being absorbed by the earth's surface. The heat created then radiates from the earth's surface heating the air near the surface. As this warmer air rises, colder air comes in to take its place. The colder air is then heated and also begins to rise. Since darker areas of the land surface tend to absorb more of the sun's energy than lighter colored areas, the air over darker colored areas tends to rise faster. Air from the lighter colored areas then moves into the areas where the air has already risen. This movement causes convection currents in the atmosphere.

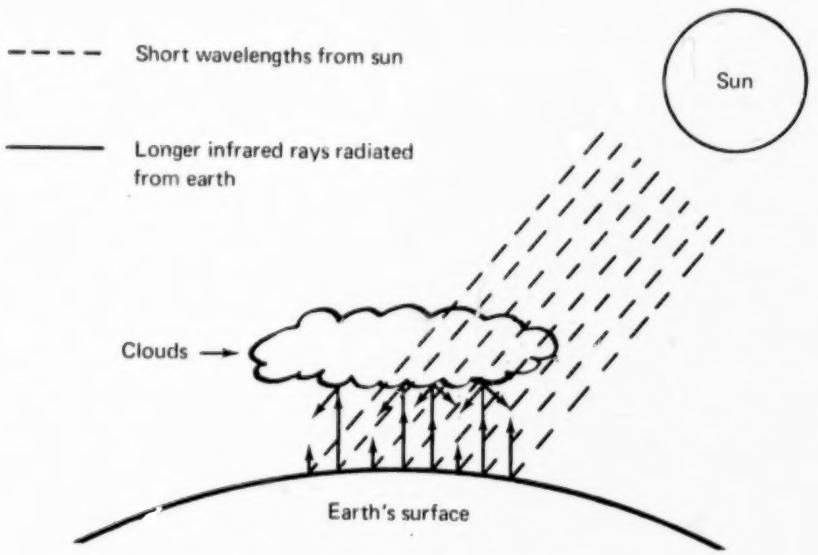


Fig. 4 Greenhouse effect.

Atmospheric Circulation

Planetary circulation is the name given to the movement of the air within the entire atmosphere. This type of circulation is due to the air movement of wind around areas of high and low pressure. Planetary circulation is caused by the greater heat received at the equator than is received at the poles. This allows the heated air at the equator to rise and the cooler air at the poles to move toward the equator. The warmer air then circulates toward the poles, cooling as it moves in that direction. The pattern of air circulation would be a rather simple one if the earth was equally heated on all sides and did not rotate. This, of course, is not the case. The earth does rotate causing a rather complicated pattern of air movements. Planetary circulation plus the earth's rotation and various other factors, such as the type of cover on the earth's surface, combine to make an overall complicated pattern of air movements. This complicated pattern of movements, in turn, has broad effects upon the weather. One of the results of this highly complex movement of air is formation of jet streams. These streams, located 4 to 6 miles high in the wintertime, are formed where the warm air rising near the equator and heading north meets the cool air heading south from the poles. In the northern hemisphere, this point is near 30° latitude. These jet streams may reach speeds up to 400 miles per hour and can sometimes be used by airplanes in the wintertime as tailwinds to speed their flights. Jet streams are not very dependable, however, as they vary in speed, direction, and extent.

Although equal-sized areas of the surface of the earth may receive the same amount of energy from the sun, some will heat up more rapidly than others. For example, land areas heat more rapidly than water areas, also, the color of the surface will affect the rate at which it is heated. Thus, when the sun is shining, land areas warm up more rapidly than water areas. Since radiation takes place from these surfaces at different rates, the air above them is also similarly affected. The warmer air above the land rises, the cooler air from over the water moves in to replace it. The movement of the cooler air is called a sea breeze. As the sun goes down, the situation reverses itself; the land cools more quickly than the water, so the cooler air over the land moves towards the warmer air over the water. Sea breezes, which take place during daylight hours, tend to be stronger than land breezes, which take place during the night.

A phenomenon similar to sea breezes and land breezes takes place in mountains and valleys. Mountains tend to absorb heat faster than valleys. This may be due in part to the fact that valleys tend to be covered with forest and vegetation, which absorb energy more slowly than the bare rocks and soil of the mountains. As the mountains warm, the air rises and the cool breeze blows into the valleys. The cool breeze that blows in from the valley and up the mountain slope is known as a valley breeze. At night the mountains cool faster than the valleys, so the process is reversed. The cooler air that descends from the mountain slopes to the valleys is called a mountain breeze.

Air masses are formed when a body of air stays over a particular part of the earth's surface for a long period of time. For example, if a body of air stays over a tropical ocean for some time, the air becomes moist and warm. These air masses tend to cover areas of millions of square miles of the earth's surface and tend to behave like oil and water – they do not mix readily with each other. The air masses that affect North America come from seven general sources. The source that generally tends to influence the weather in the Pacific Northwest is the North Pacific Ocean. Air masses that move out of the North Pacific area are known as polar maritime air masses.

Since, as has been mentioned, air masses generally do not mix when they meet, a boundary is formed between them. This boundary is called a front. Since the two air masses generally differ in temperature, the colder of the two, being more dense, stays closer to the ground pushing the warm air up. (If you are not familiar with the motion of fronts and the three types of fronts—warm, cold, and occluded, you should check these in a science book.)

Precipitation

Precipitation also has an important effect on air. There are three major conditions or storms that operate to bring evaporated water back to earth in the form of precipitation. The orographic or mountain type of storm is caused when warm air has to rise over a mountain range. A good example of this in the State of Washington is the Cascade Range. As the warm air rises to go over the mountain range, it is cooled (adiabatic cooling) causing the water vapor in the air to condense into droplets that grow larger as additional condensation takes place in the rising air until the air is no longer able to hold them up, and precipitation takes place. Orographic precipitation is generally of low intensity. However, because of the fixed location of the mountains and the general eastward movement of the moist air from the Pacific, these areas tend to have a high total rainfall.

A second type of condition or storm is the cyclonic- or low-pressure-area type. The cyclonic-type produces a general rain over wide areas. It is particularly prevalent during the winter. Cyclonic storms are produced by cold polar air masses interacting with the warm tropical air masses. In this interaction the warm moist air is lifted over the heavier cold air and at the same time cooled to form precipitation.

The third major type of condition or storm is the convectional type of storm or thunderstorm. This type is caused when a relatively small area is heated to a greater extent than the surrounding area. This may take place around a city, lake, or large open field. As any of these areas are heated more rapidly than the surrounding area, the warmed air above them begins to rise. As this air rises, cooling and condensation take place, and if this is carried to a great enough extent precipitation begins.

Two or three of these major types of conditions may work together to form different patterns of precipitation.

With this brief discussion of precipitation it is fairly easy to see why precipitation varies from over 100 inches in areas of the Pacific Northwest to less than 5 inches over certain desert areas. What happens to this precipitation? If we take an annual rainfall of 30 inches, approximately 21-1/2 inches evaporate into the atmosphere from the soil, plants, or surfaces of lakes and streams. About 3 inches seep down through the soil from rock layers into the ground layer. Approximately 5-1/2 inches run off directly into streams or move through the uppermost layers of the soil to enter the nearest streams.

SOURCES OF AIR POLLUTION

Air pollution is not new. The act of breathing causes air pollution. Early man recorded sources of air pollution. The ancient Romans complained of soot. People in England were concerned about the smoke caused by coal during the Middle Ages. The problem has been compounded with the increase of population and industrialization and has become very serious in recent times. In some respects, air pollution is a result of technological progress.

The industries that provide us the necessities of life, along with our automobiles and other conveniences, have been contributors to air pollution.

Industries

A biologist, Dr. Rene DuBois, feels that as many as two-thirds of the urban types of pollutants have not yet been identified. Industrial air pollutants include carbon monoxide, sulfur oxides, nitrogen oxides, hydrocarbons, particulate matter, and many others (see table I).

Table I.—Estimated Emissions of Air Pollutants by Weight, Nationwide, 1969
(In millions of tons per year)

Source	CO	Particulates	SO_2	HC	NO_2	Total	Percent change 1968–1969
Transportation	111.5	0.8	1.1	19.8	11.2	144.4	-1.0
Fuel combustion in stationary sources	1.8	7.2	24.4	0.9	10.0	44.3	+2.5
Industrial processes	12.0	14.4	7.5	5.5	0.2	39.6	+7.3
Solid waste disposal	7.9	1.4	0.2	2.0	0.4	11.9	-1.0
Miscellaneous	18.2	11.4	0.2	9.2	2.0	41.0	+18.5
Total	151.4	35.2	33.4	37.4	23.8	281.2	+3.2
Percent change	+1.3	+10.7	+5.7	+1.1	+4.8		

Source: *Environmental Quality: The Second Annual Report of the Council on Environmental Quality*
Note: CO = carbon monoxide, SO_2 = sulfur dioxide, HC = hydrocarbons, NO_2 = nitrogen oxide.

Approximately 58 billion pounds of these industrial pollutants are being distributed into the air in a given year. A few examples of industries that are high on the list of polluters and an estimate of the amount of pollution of each are:

Industry	Billions of Pounds of Air Pollutants
Iron, steel, aluminum, copper, lead, and zinc mills and smelters	11.9
Petroleum refining	8.4
Burning of coke	4.4
Iron foundaries	7.4
Kraft and pulp paper mills	6.6
Cement manufacture	1.7
Grain mills and handling	2.2
Phosphate fertilizer plants	0.6

Powerplants also have to be added to this list of important polluters. Total industrial processes contribute 14% to total air pollution by weight. On the other hand, transportation contributes 42%. Fuel combustion in stationary sources contributes 21%. In 1969, over 90% of the powerplants burned coal or oil containing sulfur to generate electricity. Much remains to be done to lessen air pollution and eliminate the damages from industrial air pollution.

Municipalities

Municipalities contribute to air pollution in manyways. Population is increasing, and it is estimated that there will be more than 320 million people in the United States by the year 2000–85% of them in metropolitan areas. In the past, motor vehicles have increased in number at twice the rate that people have increased. As was mentioned previously, transportation causes 42% of the air pollution, by weight, in the United States. Estimates of demand for electric power indicate that it will increase as much as five times by the year 2000. Production of electric power is also a major contributor to air pollution. Both the numbers of people and the increased standard of living contribute to more waste. Much of this waste is burned, thus contributing to air pollution. Even though air has a natural ability to take care of certain amounts of pollutants, as this ability to clean itself is exceeded, the pollution problem increases at a very rapid rate. Municipalities contribute greatly to reaching the threshold of inability of air to cleanse itself by concentrating population and industry.

Individuals

Individuals contribute to air pollution in many ways. Most industries are correcting their air pollution problems. What are you as an individual doing? Do you really care?

Using fuel, whether for heating your home or in an internal combustion engine, adds to air pollution. Many of the electrically powered conveniences used in the home add to the increase of air pollution. Burning trash and many other activities also add to air pollution. Individually we create the demand for the products industry makes thus contributing further to air pollution.

Internal Combustion Engine

Transportation is the greatest single source of air pollution. The automobile is a tremendous contributor to air pollution and is an even greater problem if it is not kept in good repair.

The Environmental Protection Agency lists the air pollution contributed by transportation in 1969 as 144.4 million tons of air pollutants for the year. By weight, that means that transportation is contributing about half of all air pollutants. Again according to the Environmental Protection Agency, transportation contributed 111.5 million tons of carbon monoxide as well as 19.8 million tons of hydrocarbons, 11.2 million tons of nitrogen oxides, 0.8 million tons of particulates, and 1.1 million tons of sulfur oxides.

What do these pollutants do?

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, poisonous gas formed when the carbon in fuels is not completely burned. Almost two-thirds of the carbon monoxide produced comes from internal combustion engines. When carbon is burned with sufficient air to ensure complete combustion, carbon dioxide forms instead of carbon monoxide. Carbon dioxide (CO_2) is found naturally in the atmosphere and is used by plants in photosynthesis (see "Plant" unit).

Hydrocarbons

Hydrocarbons (HC) also represent unburned and wasted fuel and are a source of the carbon that forms CO and CO_2. At concentrations normally found in the atmosphere, hydrocarbons are not toxic. Hydrocarbons are, however, an important factor in air pollution because of their role in forming photochemical smog. More than half of the hydrocarbons produced in the United States come from transportation sources. Since there are so many automobiles in urban areas, a high proportion of hydrocarbons are found in urban areas.

Nitrogen Oxides

Nitrogen oxides are produced by fuels burned at very high temperatures. Nearly two-fifths of all nitrogen oxides in air are produced by transportation vehicles. One of the very serious problems in controlling certain other pollutants by increasing temperatures (to burn HC and CO) is that nitrogen oxides might be increased.

Particulates

Particles in the air are called particulates. Particulates include a very wide range of sizes of particles. Some of these particles, such as smoke, are very visible. Others are too small to detect by means other than an electron microscope.

Sulfur Oxides

Sulfur oxides are corrosive, poisonous gases that are formed by burning fuels that contain sulfur. The internal combustion engine contributes less than 1% of the total sulfur oxides, and these are mostly from diesel fuels.

Agriculture

Dust is an important contributor to air pollution in the United States. Each year an equivalent of 30,000 acres of top soil enters the air. Although agriculture is not the only contributor to dust as a source of air pollution, it does contribute a major portion in the form of airborne soil.

Dust From Hay, Silage, and Grain Elevators

Filling silos, putting up hay, and handling grain may produce considerable amounts of dust and small vegetative particles that are discharged into the atmosphere. The amount of this dust will depend to a great degree on the moisture in the hay, silage, or grain and on the methods with which they are handled. Where the hay, silage, or grain are handled can also play an important role in the distribution of the dust created by these activities (e.g., locating a grain elevator in town or a silo near a feed lot or farm buildings).

Alfalfa dehydraters may be anotner source discharging dust and vegetative particles into the atmosphere. Fortunately, most alfalfa processing plants and areas where hay and silage are harvested are in rural areas. Thus, the number of people affected by the pollution problems of these activities is limited.

When silage is stored in a silo, there is the additional danger of an accumulation of nitrogen dioxide gas. Another problem that may arise in hay and silage is mold. Dust from this moldy forage can cause black lung disease. Many farmers are thought to be suffering to some extent from the dust from moldy forage and a few have died.

Dust From Harvesting

Many types of agricultural crops emit air pollutants while being harvested. Large combines harvesting small grain crops can often be seen for a considerable distance spewing forth clouds of dust and particles of vegetative material (see fig. 5). After harvesting the crop, the remains of the crop are sometimes mowed or beaten, often causing additional air pollution. Since most agricultural production is located some distance from population centers, little has been done to try to stop this problem.

Fig. 5 Combines harvesting wheat are creating some dust. USDA Photo

Airborne Soil

Airborne soil can impair health and act as an irritant to both humans and animals. Airborne soil over highways and railroad tracks decreases visibility severely. Airborne soil can also fill ditches and waterways and increase cleaning costs and time. Dust storms, such as are found almost every year in the Great Plains, have a pronounced effect on health. These storms may also impair the general conditions of the atmosphere and be very irritating to the people who live in or are traveling in the area. As well as leaving thick layers of dust on everything in their path, severe dust storms may cause automobile accidents through the severe reduction of visibility.

Severe damage may be done to machinery when airborne soil comes to rest on or in parts. Soil particles can be very abrasive and work into metal parts, especially where small clearances are required. A very few soil particles may make a diesel engine or hydraulic system inoperative.

Airborne soil may travel for hundreds of miles. Although many sections of the country have been bothered by rather severe dust storms, the Great Plains have long been the center for dust storm activity. Clouds of dust from the Great Plains have reached cities as far east as Washington, D.C.

Agricultural operations, such as tilling the soil, may also produce dust that may become airborne (see fig. 6). These sorts of activities carried on during severe wind conditions are likely to be met with more severe penalties in the future. The problem is not eased any by the fact that some dust has been found to contain pesticides and other farm chemicals.

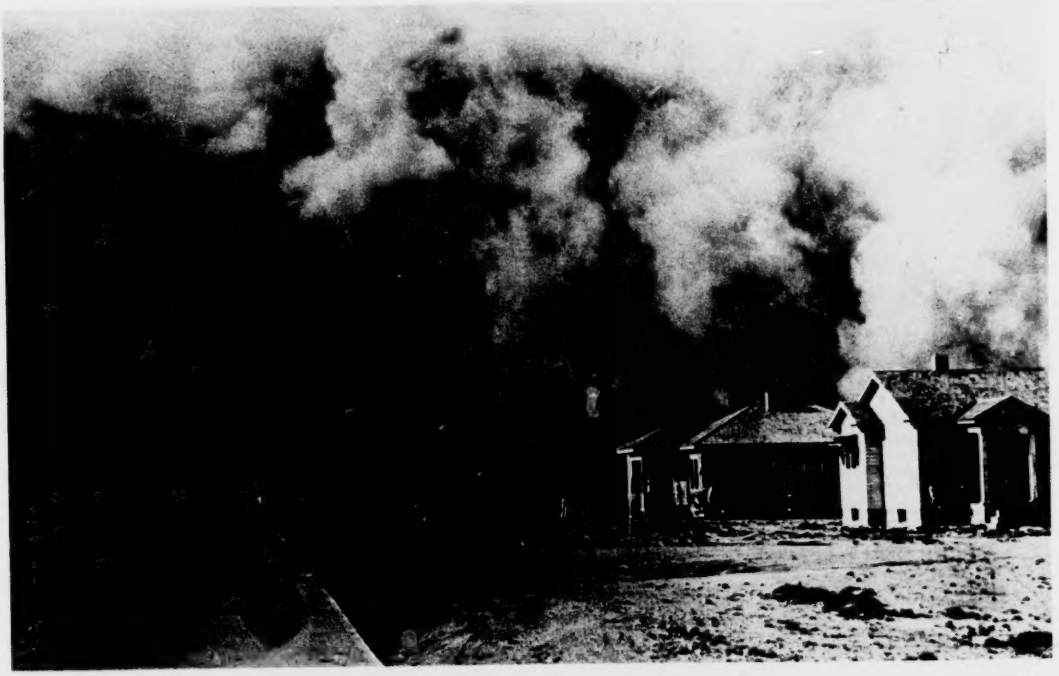


Fig. 6 People plowed land that should be grassland and saw dust storms. USDA Photo

Feedlots

Airborne material may also carry other undesirable particles. Dusts arising from feedlots, feed, bedding, or animal wastes may become serious problems. The fact that the dusts from animal wastes may have undesirable odors does not improve their acceptability. Bacteria and other disease organisms may also be carried by the wind.

Burning

Plant residues from crops, orchards, and forests have been disposed of by burning. This burning has caused considerable air pollution. If these plant residues are not burned, many of them may become reservoirs of plant diseases and a harboring place for other pests.

Approximately 900,000 acres of grass are grown for seed each year. Each of these acres produces approximately 2 tons of residue. It is estimated that, each year, approximately a third of this acreage is burned. This burning is done as a sanitation measure to control disease, which is required for high-volume production of grass seed, but the burning emits approximately 50,000 tons of particulate matter such as carbon and ash into the atmosphere. Efficient production of high-quality grass seed without burning is being investigated. Meteorological controls on the burning are also being investigated.

The emissions of hydrocarbons and oxides of nitrogen from the burning of agricultural wastes have been shown to be considerably less on a weight basis than those emitted by fuel consumed in an automobile. The few studies that have been made of the effects of burning agricultural waste indicate that such burning does not add significantly to the pollutants in community air. The effects of smoke on visibility and the amount of odor emitted may be more immediately pressing problems.

Twenty-five million tons of logging debris or slash are left behind each year. Methods of disposing of this material as well as using some of it are constantly improving. However, the material left behind is a major fire hazard. Some of the most serious forest fires have been started in debris left behind after logging or land clearing. Fires originating in logging debris are, on the average, five times larger than fires originating in uncut areas or areas where waste has been removed or otherwise disposed of. In the United States, approximately 5 to 7 million acres are destroyed by approximately 150,000 forest fires each year. Wild forest fires are an important contributor to air pollution. They contribute higher amounts of hydrocarbon and smoke per ton of fuel burned because there is usually a greater oxygen deficiency. Table II shows the amount of air pollution from prescribed burning and wild fires.

Table II.—Air Pollution From Forest Fires

Type	Smoke in convection column (cu mi)	Particulate matter (tons)	Hydrocarbons (tons)
Prescribed burning	32	6,500,000	68,000
Wild fires	160	34,000,000	338,000

Source: *Wastes in Relation to Agriculture and Forestry*

It is obvious that a way needs to be found to dispose of logging debris to keep it from becoming a fire hazard. Part of the problem is that disposing of material by chipping costs approximately $12 per ton while disposing of the same material by burning costs only $1 per ton. Prescribed burning may also cause other problems. The visibility may be lowered to the point where it causes automobile accidents and limits recreation activities. Apple growers in Washington and Oregon have filed suits against the United States Forest Service because they claim that smoke from prescribed burning has prevented proper apple coloration.

Frost prevention in orchards may also be a source of air pollution. Fires or smudge pots sometimes used to prevent frost in orchards cause air pollution. Restrictions on the types of apparatus that can be used for frost protection are now in effect in many states.

Chemicals

Burning of plant residues distributes a certain amount of chemicals in the air. Pesticides being applied to crops or animals may drift through the air for many miles. Airborne soil may also carry chemicals with it. The fact that chemicals used by agriculture are in the air is little disputed. The amount of damage done by these materials is much harder to determine. Many chemicals affect plants even in very low amounts. Fish kills, crop yield reduction, and damage to ornamental shrubs and plants are some of the most common complaints investigated.

COSTS OF AIR POLLUTION

Air pollution has many adverse effects on man and his environment. The most important aspect of air pollution is the fact that it endangers man's health. It also lowers the value of agricultural products and interferes with animal health. Air pollution dirties a man's home and hinders the growth of plants and shrubs used to decorate it. Air pollution may also cut down on the amount of the sun's rays reaching the earth's surface, limit visibility, and give off unpleasant odors. The damage done by air pollution depends to a great degree on how weather disposes of the pollutants.

The atmosphere has a limited ability to dilute and disperse pollutants. Two of the major factors influencing the atmosphere's ability to dilute and disperse these pollutants are wind speed and the depth of the atmosphere in which the pollutants can be spread. Although almost daily fluctuations take place in the atmosphere's ability to disperse air pollution in any given place, longer term patterns can be determined. In many places, extreme fluctuations in air pollution may be experienced. Air pollution is usually less of a problem when strong winds are blowing, but days with weak winds and highly stable conditions may allow large quantities of pollutants to accumulate. Many cities lie in natural basins such as flat areas near mountains, near bays, or near rivers. These natural basins are the types of places where concentrations of low-lying masses of warm air may occur. These low-lying masses of air trap pollutants and create a phenomenon called an inversion.

Damages to Human and Animal Health

Damage to human health is the most important aspect of air pollution. Air pollution is especially serious for elderly persons and those who have respiratory or cardiac conditions. An incident such as the inversion that occurred in 1948 in Donora, Pennsylvania, should be of concern to all Americans. Twenty persons out of a population of 14,000 died. Of much greater concern for most Americans, however, is the effect on health of the nearly continuous exposure to lower levels of pollution.

It is extremely difficult to assess the damage that is done by particular pollutants. The large number of pollutants, combined with biological and physical stresses, make it nearly impossible to assess the amount of contribution to a particular type of disease by each. There is, however, little doubt that air pollution does contribute to the incidence of many chronic diseases. Air pollution can be linked to such chronic diseases as emphysema, bronchitis, and other respiratory ailments, as well as to higher mortality rates. Polluted air is also linked to higher mortality rates from cancer and arteriosclerotic heart disease. People who smoke and live in polluted cities have a much higher rate of lung cancer than people who smoke and live in rural areas.

The number of persons suffering from chronic diseases has increased rapidly during this century. The infectious diseases that have caused great epidemics and large numbers of deaths in the past have largely been brought under control. More than half the deaths in the United States in 1962 were caused by heart and blood vessel diseases. Lung cancer and emphysema have increased rapidly in the past several years.

Although much remains to be determined about the results of air pollution upon certain kinds of health disorders, the most obvious health defects are being determined for major classes of pollutants. When carbon monoxide (CO) is breathed in it replaces oxygen in the blood and reduces the amount of oxygen carried to body tissues. The reactions of even the healthiest persons can be slowed considerably by amounts of CO found in major cities. This slowing of reaction time can make the person more accident prone and slow his ability to complete work.

Studies have shown that exposure to as little as 10 parts per million of CO for approximately an average working day may dull mental performance. Levels of 10 parts per million are not uncommon in cities throughout the world. In heavy traffic, levels of 70, 80, or 90 parts per million of CO are not uncommon for brief periods.

Ozone alerts in California occur when ozone is too high; automobiles are stopped and industry goes to alternate power sources or closes down.

Sulfur oxides can produce temporary or permanent injury to the respiratory system. The damage to health increases significantly when particulate matter is inhaled with the sulfur oxides. Many of the most severe disasters caused by pollution in recent years were caused by sharply increased levels of sulfur oxides and particulates.

Sulfur dioxide (SO_2) can irritate the upper respiratory tract and, if carried into the lungs on particles, will injure delicate tissue. Sulfur trioxide (SO_3) combined with water forms sulfuric acid. Sulfuric acid, of course, penetrates flesh quite readily. Health may be damaged when the annual mean concentration of sulfur dioxide is above 0.04 parts per million. Deaths from bronchitis and lung cancer may increase when this level of sulfur dioxide and concentrations of approximately 0.06 parts per million of smoke are present at the same time.

Sulfur oxides may affect health if they exceed 0.11 parts per million for 3 or 4 days. Many large American cities have been observed to exceed 0.11 parts per million of sulfur

oxides during inversions. The effects on health of photochemical oxidants have only recently become a source of major research. Studies have shown that eye irritation begins when peak oxidant levels reach 0.01 parts per million. Increased frequency of asthma attacks have also been linked with increased photochemical oxidants. Less is known about the effects of nitrogen oxide, but evidence to this point would suggest that it may be harmful to human health.

Certain fairly specialized materials may be closely related to human health. For example, beryllium, which may be emitted from industrial sources, is very dangerous. Another long-recognized danger is from asbestos. It is increasingly found in air because of its use as a construction material and for brake linings and other products. Its use in brake linings has been highly criticized since small particles are worn from the brake linings and allowed to escape into the air. Long exposure to asbestos has been shown to cause a lung scarring disease called asbestosis. Mercury and lead are other materials that have been shown to be very dangerous.

Many other pollutants are being considered as to their effects on health. There is considerable concern that the levels of lead found in the human body may interfere with the ability to produce blood. The lead in the human body at present, however, is considerably below that required for lead poisoning. Lead levels may continue to increase as airborne lead increases, mainly from automotive exhaust.

Air pollution damage to livestock is also widespread. Many types of animal diseases are carried by air. These infectious agents cause diseases that affect livestock, poultry, and many other types of animals. The dollar amount of damage done by these infectious agents is not known, but it is known to be large.

Dust storms have also been shown to adversely affect livestock and poultry. Besides irritating the eyes, nose, and other parts of the body, they increase mortality rates and incidences of certain diseases.

A bone disease in cattle called fluorosis has been found in many parts of the country. Fluorosis is caused by fluoride compounds and is particularly prevalent near such industries as steel and aluminum mills and phosphate fertilizer plants. In extremely severe cases of fluorosis, animals cannot bear the pain of standing (see fig. 7).

There are seven aluminum smelters in Washington, all of which use alumina (Al_2O_3) and reduce it by an oxidation-reduction reaction using aluminum fluoride as a catalyst to form aluminum (Al) and give off fluoride gas (F) and CO_2, CO, etc. In Whatcom County near Ferndale, Intalco Aluminum Corporation has a problem regarding fluorosis. The fluoride gas is less than 1 micron in size and has escaped the water scrubber, thus Intalco is now installing a dry scrubber that unites the F ion with the Al_2O_3 and forms aluminum fluoride with oxygen as a byproduct. This method has been used by Alcoa with much success (98.5% efficient).

Intalco has many lawsuits pending regarding damage done to livestock and land caused by fluoride. A precedent was set when a farmer asking for $800,000 damages was given $80,000 by a jury in March 1972.

Damages to Esthetics and Visibility

Air pollution limits visibility and hides scenic beauty. Particulates (ash, carbon, dust, and liquid particles) both scatter and absorb light; particles are also formed in the atmosphere by photochemical actions. Whenever relative humidity rises and sulfur oxide is present, the water content of the air can convert the sulfur oxide to sulfuric acid mist, thus reducing visibility. Sulfur pollution, of course, exists wherever large amounts of coal or oil that contain sulfur are burned. (Alaskan oil is fairly high in sulfur so that the new refineries being constructed to refine the crude oil from such areas need to be as up to date technologically as possible.)

Nitrogen dioxide forms a brown haze that can be seen over the morning sky in many cities during rush-hour traffic. Many of these particulates, especially soot and other such dark-colored, sticky materials, land on white or light colored buildings such as capital domes thus rapidly diminishing their beauty (see fig. 8). Hydrogen sulfide (H_2S) also affects buildings—it blackens lead-base paints.

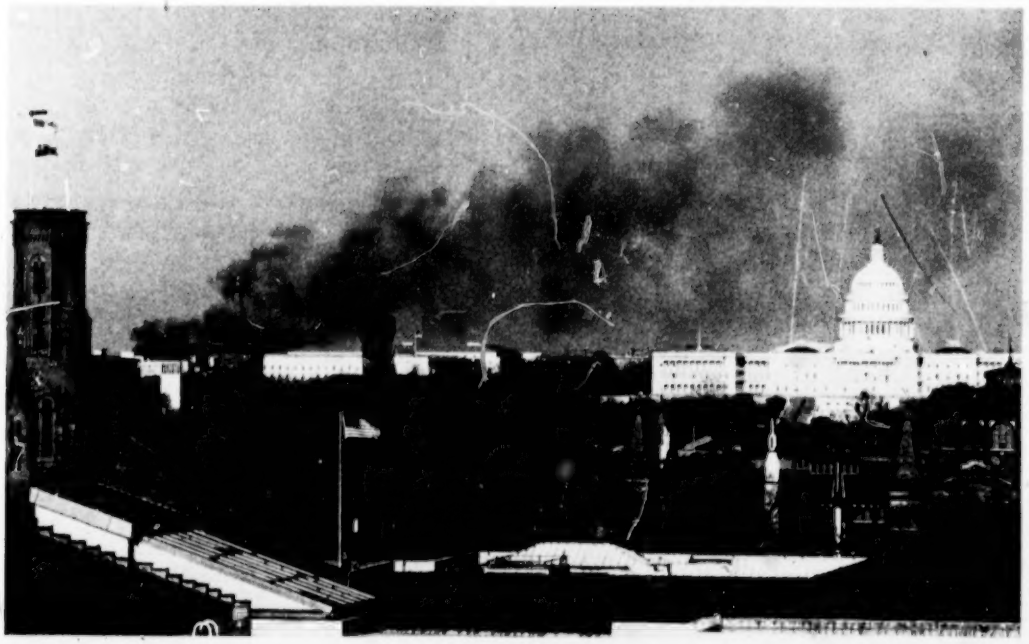
It is suspected that many automobile and aircraft accidents are caused at least in part by low visibility due to air pollution. In Los Angeles, which has severe smog problems, smog frequently lowers the visibility to less than 3 miles. In some of the large eastern cities, visibility has at times been almost totally obscured (see fig. 9).

Damages to Climate

Most of man's effect upon climate and weather is inadvertent. Even less encouraging is the fact that very little is known as to what changes are taking place or exactly what is

Courtesy: William F. Harris, D.V.M., Puyallup, Wa.

Fig. 7 Cow suffering from a bone disease caused by fluoride poisoning. Note the damage to the bones. In extreme cases, the animals cannot tolerate the anguish of standing.



USDA Photo by Jack Hayes

Fig. 8 Smoke from the Kenilworth dump where Washington, D.C. trash is burned billows over the Capitol of the United States.

USDA Photo

Fig. 9 Manhattan Island is shown in the smog.

causing them. It is possible that, by man's actions, the average air temperature might be changed enough so that we could enter a new and disastrous ice age or an equally disastrous melting of the ice caps, which could cause severe flooding. Since these damages have occurred in the past without mans' help, they may occur sooner in the future with man's inadvertent help.

There seems to be growing evidence that man's activities and his growing population are altering the chemical composition of the atmosphere and are also changing its heat balance. These changes are working together to alter weather and climate, but the kinds of changes likely to take place are to a large extent unknown.

Climate is a very complicated series of phenomena. It cannot be measured by any single or even a few measurements. A change in one aspect of the climate may change other aspects. For example, temperature changes may have a great effect on rainfall.

What is man doing that may change his environment? Several things he does may at least slightly change atmospheric temperature, and these slight changes may significantly affect climate. Adding carbon dioxide to the atmosphere is one way man may be affecting the atmosphere. Energy rays from the sun enter the earth's atmosphere and are virtually unaffected by carbon dioxide. As the sun's energy hits the surface of the earth it is absorbed by rocks and other materials. After absorption at the earth's surface, much of this energy is radiated back toward space. The radiated energy has been transformed, however, so that is is now infrared heat radiation, which has a much longer wavelength. Carbon dioxide acts as a barrier to these longer wavelengths of radiation so that heat loss through radiation decreases as carbon dioxide concentrations increase. This increases the "greenhouse" effect causing the average temperatures to rise.

Recent findings seem to show that, as the output of carbon dioxide increases, higher percentages of it are absorbed by the ocean. Thus, the percentage of carbon dioxide in the atmosphere is not increasing nearly as fast as it is being produced. This leads many observers to the conclusion that the danger of carbon dioxide in the atmosphere changing the climate may not be as great as has been predicted, but, of course, the carbon dioxide may then change the oceans. Unfortunately, present evidence is so sketchy as to make future predictions little more than guesswork.

Particulate pollution of the earth, that is, the addition of particles to the air, may affect the amount of radiation reaching the earth and thereby lower the temperature. Particulate pollution may therefore help compensate for any carbon dioxide generated temperature rises.

Some kinds of industrial processes give off small particles around which raindrops can form. These small particles can affect the amount of low cloud layers and the frequency with which fog occurs. Fog and low cloud layers can in turn influence the radiation that reaches the earth from the sun. Prescribed burning as well as wild forest fires may also emit dust and ashes plus large quantities of heat and water vapor that may also cut down the radiation received from the sun. The total effects of any or all of these activities depends on the amount, size, distribution, and altitude of the particles. Estimates as to the changes in temperature due to particulate air pollution vary greatly.

The fact that fog and low clouds increase when an urban area is established in what was previously open country has been well documented. It is not known whether there has been any increase in cloud cover around the entire earth. Satellites are now doing a better job of measuring the total cloud cover and will allow better observations in the future as to whether cloud cover is increasing.

Water vapor in the higher atmosphere can also upset the earth's radiation balance by absorbing outgoing infrared radiation. If this water vapor is in the form of ice crystals, it can also block incoming solar radiation. It is estimated that a rise of the stratospheric water vapor content from two to six parts per million could increase the earth's average surface temperature about 0.9°F. The burning of jet fuel by aircraft adds water to the earth's atmosphere. United States domestic airplanes used 7 billion gallons of jet fuel in 1970. Water vapor below the stratosphere dilutes quickly and adds very little to the long-term presence of water vapor at these altitudes. On the average, water vapor above the stratosphere stays for about 18 months. This occurs because the water vapor mixes so slowly with the atmosphere from lower altitudes. Most commercial jets fly below the stratosphere. Plans for future supersonic jets, however, call for flights at altitudes from 60,000 to 70,000 feet. Although the amount of water vapor that would be distributed into the stratosphere seems relatively insignificant, much more research needs to be done on supersonic transports.

The long-term effects of high cloud cover is not yet known. There is evidence, however, that jet aircraft are contributing to high clouds.

Thermal pollution is another concern to many people. Man's activities add only very slightly to the earth's heat. If this heat produced by man was averaged over the earth's surface, it would amount only to about one ten-thousandth of the net radiation gain of the atmosphere. This small amount of heat which is concentrated in and around the cities, would be insignificant in changing the climate when spread over the entire surface of the earth. This increase in heat around cities may influence the climate surrounding them. As man's demands for more electrical energy and other sources of power increases in the future, increased heat may rise to the point of being of major importance. The increased demand for energy, coupled with rapidly increasing population, could have wide-reaching effects. The production of energy gives off heat pollution. The production of energy also may give off carbon dioxide or particulate pollution. The presence of carbon dioxide raises atmospheric temperature, and particulate pollution lowers it. We do not presently have the needed information to know if these opposite trends will balance themselves.

Changing the earth's surface characteristics also changes the surface's ability to absorb radiation from the sun. Covering an area with asphalt or concrete thus changes the ability of the area to absorb radiation. Densely built-up areas tend to have higher reflective surface characteristics than areas in forest or agricultural production. Deserts also have a much higher surface reflective characteristic than do grass-covered fields. Some scientists claim that man is affecting the amount and location of deserts.

It has been known for many years that cities and adjacent rural areas have noticeably different climates. Increasing sources of information show that industrial activities are modifying atmospheric properties. In some cases, this modification of atmospheric properties is also affecting the weather. Some of the differences in the climate in cities as compared to nearby rural areas can be seen in table III.

Several factors contribute to the warmer climate of a city. Heat is contributed from homes and industry. Buildings and other structures may shelter the city from winds thus lowering wind speeds. The increased cloudiness plus the effects of buildings and pavements on the amount of radiation retained also increases the heat retained.

Cities also generally receive increased rain and snowfall. This is probably caused by a variety of factors, but one may well be the warmer air in the city which pushes the oncoming air masses to a higher cooler altitude where they release some of their precipitation. Also, some of the particulates produced in metropolitan areas act as nuclei

around which water vapor condenses to form drops. It has been shown at the University of Washington that particulates from certain Washington State pulp and paper mills are prolific sources of cloud condensation nuclei. It has also been shown that clouds form downwind from the mills. Although more research needs to be done in the area of particulate precipitation, it seems evident that particulate matter is having an effect on the weather.

The effect of an oil film on water surface is still poorly understood. The oceans act somewhat as a balance wheel to climate. The atmosphere exchanges energy with the ocean through radiation and other processes. The interaction of the air moving over the water is a complicated process. Very thin films of oil can alter the interaction and cut down the turbulence of the air against the water, decrease the evaporation, and reduce the radiation emission from the surface of the water. It is still not known if oil pollution is seriously changing the climate.

Damages to Vegetation

Since airborne dust may carry pesticides with it, it may damage plants by carrying pesticides to the plants. For example, herbicides many miles away can be carried by dust and be deposited on a crop highly sensitive to this type of herbicide with disastrous results. If insecticides were carried to a lettuce crop, it could be rendered inedible by the accumulation of these insecticides. Just the accumulation of dust on a leafy vegetable such as lettuce may considerably lower its quality. Fruits may also be damaged by an accumulation of dust.

An accumulation of dust on leaves cuts down on the amount of sunlight reaching and being usable to the leaf. As sunlight is cut down, photosynthesis is interfered with. Dust accumulations may also affect the leaf stomata which permit gas exchange between the

Table III.—Climatic Differences Between Cities and Rural Areas

Climate factor	City as compared with rural surroundings
Temperature	
Annual mean	0.9° to 1.4° F higher
Winter minimum	2° to 3° F higher
Cloudiness	
Clouds	5% to 10% more
Fog, winter	100% more
Fog, summer	30% more
Dust particles	10 times more
Wind speed	
Annual mean	20% to 30% lower
Extreme gusts	10% to 20% lower
Precipitation	5% to 10% lower

Source: *Environmental Quality: The First Annual Report of the Council on Environmental Quality*

leaves and the surrounding atmosphere. When these processes are interfered with, the growth of the plant is retarded. Dust that accumulates on greenhouses may cut down the amount of light available inside the greenhouse and thus interfere with plant growth. This is a particularly serious problem in the wintertime when there is less sunlight available.

A dust-carrying windstorm can completely destroy a stand of young plants. The dust beating against the plants is very similar to sand blasting. Considerable amounts of this type of wind-blown dust damage occurs in the Atlantic coastal plain. Serious damage to young plants has also been recorded in midwestern states.

In addition to the natural-type dusts, industrial dust pollutants may have severe effects on plants. Although dust from natural sources, from agricultural sources, and highway and industrial construction do considerable damage, certain industrial dusts may be even more serious. Examples include certain mining operations such as strip mines, mineral processing operations such as cement plants, fly ash from filters, and dust from cotton gins and feedlots.

Sulfur dioxide from metal smelting plants and oil refineries may severely damage many types of crops and forests. There is less likelihood today of the dramatic type of plant damage that has been seen near smelters and other industrial operations in the past. This is due mainly to improved laws and increased enforcement as well as better understanding and better equipment being used by industrial concerns. However, there is still considerable slower acting air pollution damage taking place in agricultural crops, forests, and ornamental vegetation (see fig. 10).

Sulfur oxides and fluoride produced by phosphate fertilizer processing plants have been known to damage a large number of various types of plants. Livestock that graze on vegetation with fluoride deposits may develop a crippling condition known as fluorosis. New

USDA Photo

Fig. 10 Contrast between grafted eastern white pines after 7 months' exposure to a polluted area (left) and to an area free of pollution (right).

Jersey, which is known as the Garden State, has had injury to vegetation reported in every county, and damage to at least 36 commercial crops has been reported.

Smog in the Los Angeles area has contributed to a slow decline in the number of citrus groves south of the city. San Bernadino National Forest 50 miles away has also received damage.

Ozone, one of the major photochemical oxidants, has damaged a wide variety of plants. Long-term ozone exposure to as little as 0.05 parts per million can reduce radish yields by as much as 50%. Another important agricultural crop, tobacco, is sensitive to ozone at even lower levels (see fig. 11).

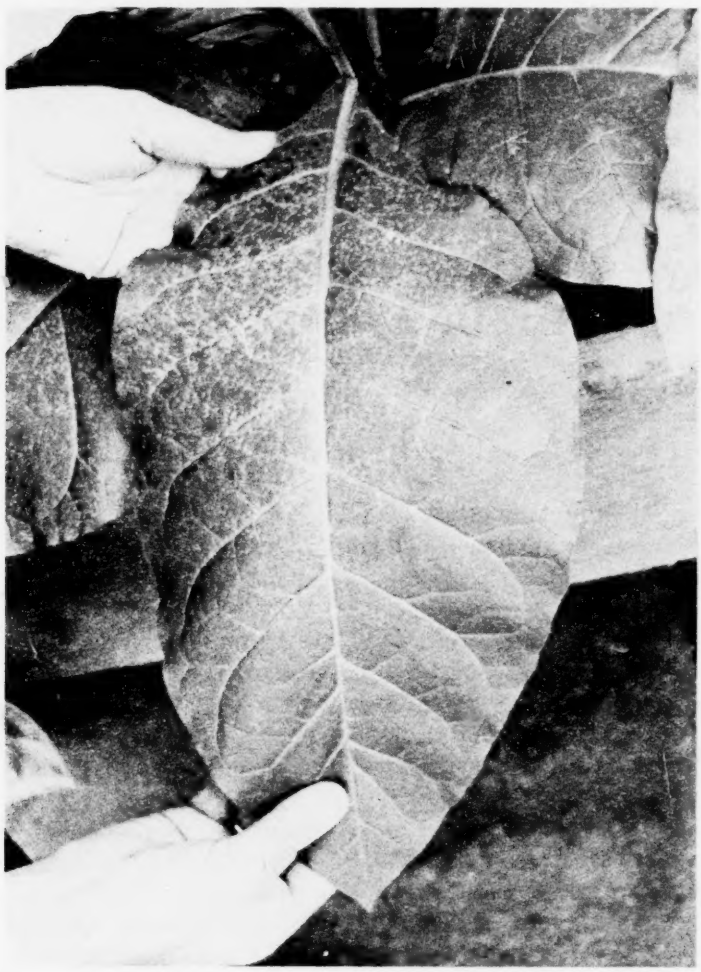


Fig. 11 The leaf of an ozone-sensitive tobacco variety shows white spots characteristic of air pollution damage. USDA Photo

Other Damages

Sulfur oxides destroy many materials. Steel corrodes two to four times faster in urban industrial areas than it does in rural areas. If particulate matter is added to the sulfur oxides, the corrosion rates multiply. Sulfur oxides are accelerating the erosion of buildings and statuary in many parts of the world. In some cities, such works of arts as statuary made of stone, bronze, or steel must be moved inside to protect them. (Marble statues in Italy are dissolving from acid mist.) Sulfur oxides may also deteriorate soil and otherwise damage textiles and other materials.

Ozone also damages textiles, discolors dyes, and greatly accelerates the cracking of rubber.

It is impossible to give any kind of exact estimates as to the cost in dollars of air pollution. For example, the average person breathes 30 pounds of air per day. If this air is polluted, it can cause many serious diseases or contribute to many other diseases. What kind of cost

can be placed on human life or health? It is estimated that we in the United States put nearly 200 million tons of air pollutants in the air each year. These include carbon monoxide, sulfur oxide, nitrogen oxide, hydrocarbons, particles, and photochemical smog. Although it is extremely difficult to estimate the total costs, many estimates put the cost of air pollution at over $12 billion per year in the United States. Again, an important question to ask is what kind of charge should be made for shorter life, chronic diseases, or death. Unfortunately, the damages from air pollution are great. However, the problem is getting worse. The population is increasing and there are more automobiles. The demand for power is increasing and more wastes are being created. Wastes are important because some of these are burned, producing more air pollution.

What can and is being done to promote air pollution control? Let's take a look.

CONTROL OF AIR POLLUTION

It has been estimated that more than $100 billion will be spent in fighting air pollution in this country alone by the end of this century. There is little doubt that such investments are necessary and desirable. The spending of this kind of money, however, points out the importance of expanded research. Many of the answers to air pollution will not be quick and easy ones. A great number of well-trained persons in many disciplines will be required to get the job done. It will require a sustained effort and will take not only large monetary investments, but also massive expenditures of time and energy.

Industries

Many industries have spent considerable money in trying to lessen their contribution to air pollution. Along with the initial capital outlay, upkeep and operation costs continue to rise as additional air treatment facilities are put into operation. By 1968, the steel industry had invested $316 million in air quality systems. By the end of the 1960's, the pulp and paper industry had spent over $138 million for new equipment. All the older kraft pulp mills (brown paper) in Washington and Oregon have been required to reduce odoriferous compounds by 85% by 1972 and 95% by 1975. It is estimated that, to meet these standards by 1975, approximately $85 million will be required.

Many processes can be applied to remove particles before emission into the air. These include filtering, electrostatic precipitation (see fig. 12), and removal by centrifuges, cyclones, and settling chambers. Poisonous gases can likewise be removed by burning them to form harmless products, absorbing them on charcoal or other such material, and by using scrubbers to wash them out. In some instances, fuels low in their ability to pollute may be substituted for the fuels that do much more polluting. For example, coal might be replaced in some operations by natural gas or atomic energy.

Improved processes need to be developed by industry to help abate air pollution. A massive effort of recycling and reclaiming waste byproducts needs to be implemented to help eliminate air pollution. By recycling air, the amount of air being polluted can also be cut down.

Many wastes being emitted as particles or gases and causing air pollution problems can be salvaged and used. Sulfur oxides can be collected, and the sulfur, which has been polluting the air, can be reclaimed and used for gainful purposes. If this sulfur were used to

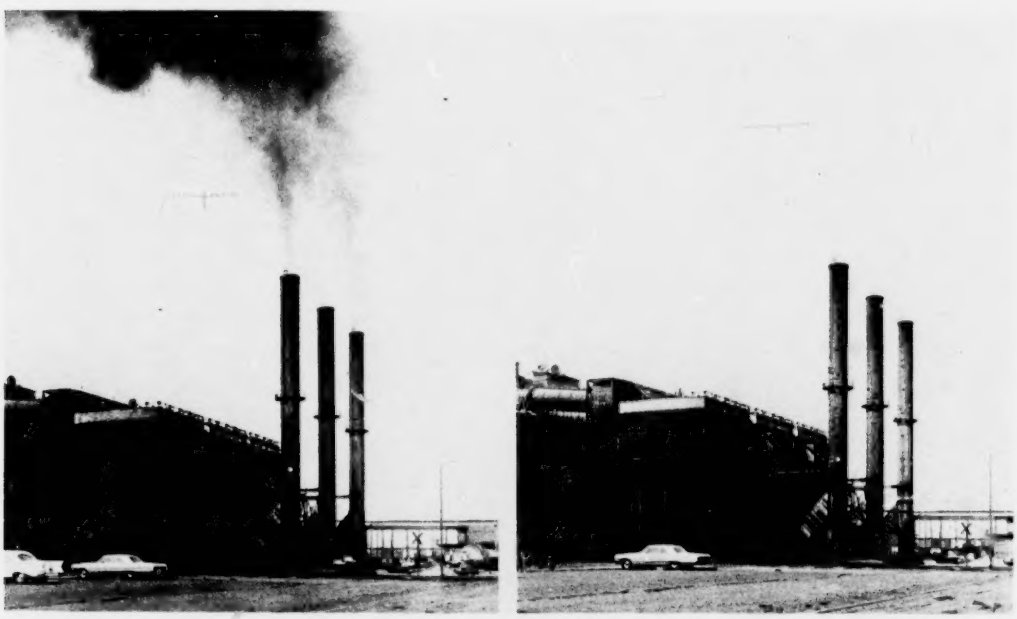
make sulfuric acid, for example, this could decrease pollution from sulfuric acid plants. Industries can use higher grades of fuel. Industries can also develop methods of production that will require less fuel.

Industries must take on the responsibility of obeying air pollution laws. Some industries have tried and are continuing to try to evade or avoid laws rather than to comply with them. For example, it has been cheaper for many firms to pay the low fines imposed or to stall rather than to try to improve their control of air pollution. Fortunately for all of us, some industries are already taking many of the recommended actions.

Government

There are several things that cities and states can do to help control air pollution. Laws and ordinances can be passed that will help to control air pollution. Joint agencies between cities, states, and the federal government can be established to obtain better control of air pollution through cooperation.

Most cities have large amounts of waste. Better methods of disposing of this waste are already known and can be adoped by most cities. Cities using incinerators can make sure that they are properly maintained and operated to ensure minimal air pollution. Incinerators that are not functioning properly should be replaced by new and better models. Alternate methods of disposing of some types of wastes may have to be found. For example, newspapers may be used as fertilizer, cattle food, or more newspapers. Mass transit systems are needed in many large metropolitan areas where they can help reduce the use of internal combustion engines for travel.



Kaiser Graphic Arts Photo

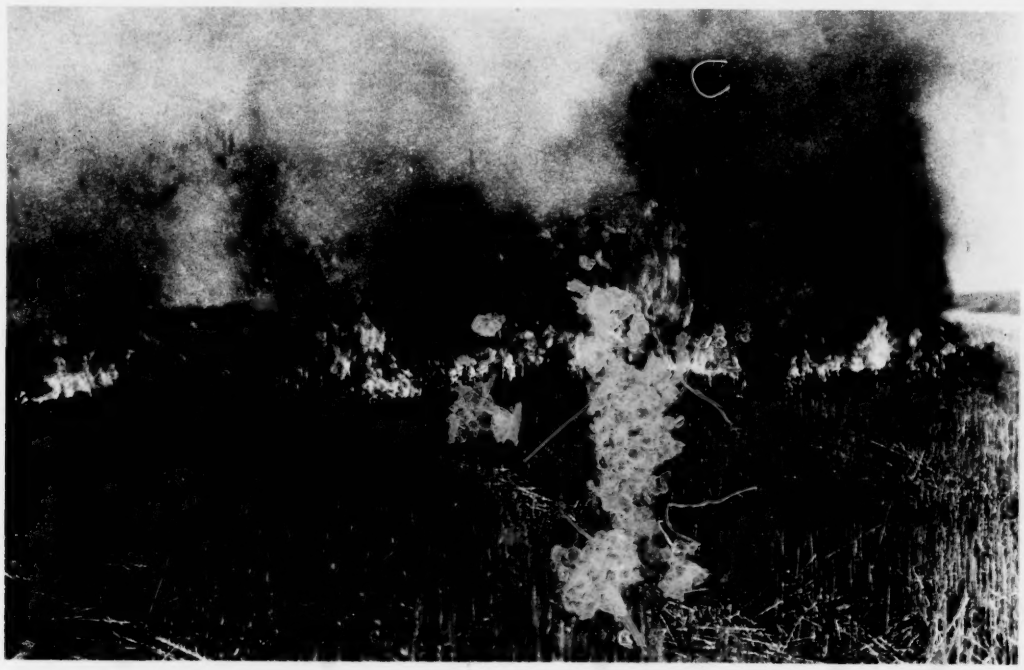
Fig. 12 These photographs demonstrate the effectiveness of the air pollution control equipment on Kaiser Steel Corporation's oxygen steelmaking plant. Picture at left shows emissions created when the electrostatic precipitators were turned off. At right, the precipitators are back in operation.

Individuals

Individuals can help control air pollution by informing themselves about the problems involved. They must be willing to pay the taxes and the higher costs of products to help control air pollution. They can vote to support government programs that help to control air pollution. They can observe open-burning ordinances or laws concerning proper use of incinerators. They can also make sure that they meet minimum standards in all areas of air pollution, including keeping their automobiles properly tuned and using lead-free gas. It is also possible that they can cut down the use of their automobiles by riding bikes or walking when going short distances. Individuals can cut down on their consumption of power by avoiding use of air conditioners and other appliances when not necessary. Individuals can burn fuels that cause less pollution in their home heating systems and can make sure that their heating systems are properly adjusted and operated.

Agriculture

Many things can be done in agriculture to try to control air pollution. Where possible, land can be kept covered, especially during dry seasons, to help prevent soil particles from becoming airborne. Farmers can avoid working land on days when winds are strong. Farmers can use methods of harvesting, planting, and other operations that minimize air pollution. More care can be taken in harvesting and storing hay and silage to avoid the formation of black mold. Farmers can establish wind breaks and use other practices that help to prevent air pollution. Prescribed burning of forests and grasslands (see fig. 13) needs to be held to a minimum and done at the times when the least possible air pollution will take place.



USDA Photo

Fig. 13 Burning wheat stubble causes air pollution.

Although many improvements have been made in controlling air pollution, much research needs to be done.

Present Situation

The public's concern for water pollution seems to take precedence over many other areas of pollution control. The first permanent water pollution legislation was enacted in 1956, but it was not until 1963 that the first permanent air pollution legislation was passed.

There are three major reasons for this lag in air pollution abatement. First, there is no available technology to remove some of the air pollutants. Second, few states have had adequate manpower or in many cases even a state agency for air pollution abatement for many years. Third, federal legislation is not presently adequate to meet the current pollution problems. In addition, the procedures for development and implementation of air pollution standards take too much time and effort by both state and federal governmental agencies.

Even though air pollution abatement is not as advanced as water pollution abatement, it is improving rapidly. Since 1963, all states have adopted air emission standards, and almost all states inspect facilities causing pollution and have authority to enjoin standards violators.

When looking at the present situation, it is valuable to distinguish between stationary sources of pollution and mobile sources of pollution. This is true because the methods of control are very different for the two sources.

Stationary Sources of Pollution

Air pollution abatement controls are sometimes easier to apply to stationary sources than to mobile sources because they remain in one place. Particles can be removed by filtering, electrostatic precipitation, or by centrifuges. Each of these devices tends to be easier to install on stationary sources of air pollution. Likewise scrubbers, charcoal absorbing materials, or burning to form harmless products tend to be done more easily at a stationary source. Also, more types of fuel can be used for stationary sources.

Mobile Sources of Pollution

Control of mobile sources of pollution is a great challenge. Since 42% of air pollution by weight is caused by transportation, this is a most important problem. Although, starting with 1968 model automobiles, pollution controls are required by the federal government, only partial success has been achieved. This is due in part to the fact that control systems on vehicles in use by the public have lost their effectiveness more rapidly than was the case with test vehicles and have also tended to lower gas mileage, another contributor to pollution. This, of course, has made the program less effective than was projected. Another problem is the fact that there are millions of automobiles being operated that have no control systems or are equipped with devices that are not doing the job. Present expectations are that emissions will continue to be reduced as they have in the recent past and will drop further when the 1973 and 1975 standards take effect.

Monitoring

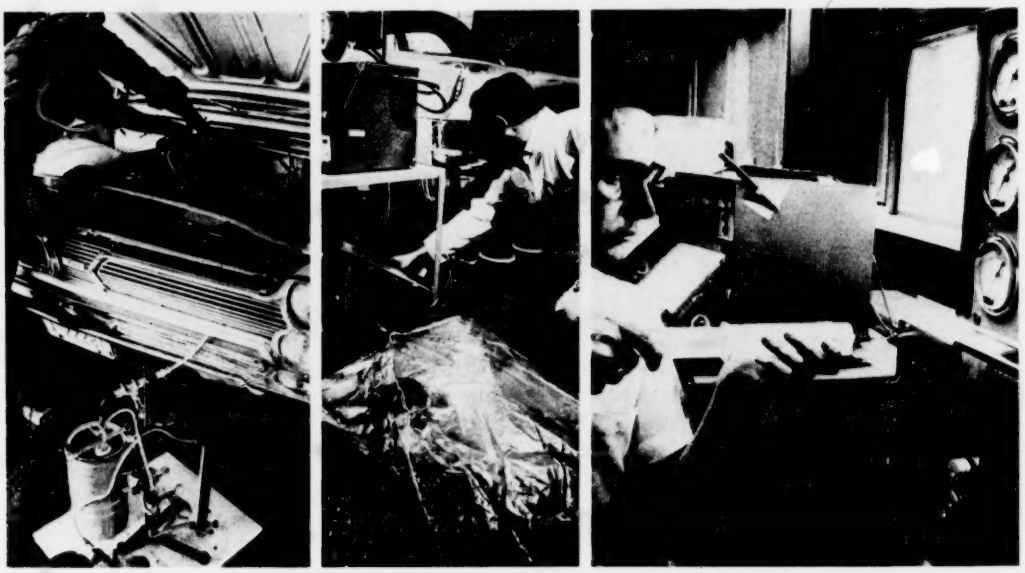
Because the number of people and the amount of equipment available for monitoring is limited, it is usually located in high population centers. The highest growth areas are often not even monitored. There are many types of pollutants none of which necessarily increase or decrease in quantity at the same rates. Thus, at the time the measurement of a monitored pollutant may be decreasing, other pollutants not being measured may actually be increasing.

There is little question that most cities with populations above 50,000 have air pollution problems. In our major urban areas, the levels of air pollution are above levels at which adverse effects are found on human health, vegetation, buildings, statues, and other materials. Improved monitoring of air pollution is badly needed to help understand the present situation and trend in air quality. The accumulation of this information will be very useful in the development of better control programs for the future.

The collection and evaluation of data on air pollutant emissions requires joint federal, state, and local effort. The Environmental Protection Agency (EPA) is cooperating with state and local agencies in the development of monitoring activities. EPA's air monitoring program involves the operation of more than 1000 air sampling devices in stations across the country (see fig. 14). State and local governments operate over 2000 stations.

Governmental Programs

The results being obtained under the 1967 Clean Air Act have been gained at an extremely slow pace. However, some action is being carried out under the enforcement



Bureau of Mines, U.S. Dept. of Interior Photos

Fig. 14 From carburetor and from tailpipe, samples of hydrocarbon emissions are collected under controlled-test conditions (left, center) and then pumped into an analyzer (right) at a Bureau of Mines Research Center. What comes out is a relationship between exhaust-gas composition and the variables of engine operation.

provisions of the 1970 amendments to the act. The conference and public hearing procedure set up under the 1963 Clean Air Act has been found to be a cumbersome and time-consuming method of taking action against individual polluters. The first and only completed action under the act took over 5 years. Conferences held to date have been aimed basically at strengthening state and local efforts.

Few enforcement proceedings have taken place under the 1967 act because it took so much time to improve the standards and implementation plans to the point where they could be enforced.

Newer and stricter standards for air pollution control are being set for federal legislation. Both the testing procedures and exhaust standards are being tightened for automobiles. Even with the tightening of standards, many automobiles will continue to be serious polluters. This is due in part to the fact that pollution systems break down, are not sufficiently durable, or the car's owner does not provide proper maintenance.

Fuels and fuel additives used for internal combustion engines also must be studied. The most important additive from an air pollution control viewpoint is tetraethyl lead. Tetraethyl lead accounts for a significant portion of particulate pollution from automobiles.

Another important area of governmental concern is that of sulfur oxides. Sulfur oxides are important because of their serious effects on human health as well as because they are so harmful to vegetation, buildings, and materials. Much sulfur oxide comes from the coal and oil being burned to generate electric power. This makes removal of sulfur oxides even more challenging since the electric power industry is nearly doubling its output every 10 years. Although nuclear power is increasing as a source of energy, coal and oil are now and will continue to be major sources of energy for the rest of this century.

Many things remain to be learned about controlling air pollution. The EPA is carrying on extensive research, development, and demonstration programs. These programs are going on in their own facilities as well as through grants and contracts. In the 1970 fiscal year, nearly $60 million was budgeted for research and demonstration. Two principal areas are given high priority. The first is the development of controls of stationary sources of pollution. Under this program, new methods of controlling sulfur oxides of stationary sources are being worked on. A new program similar in nature is being started to develop similar techniques for controlling nitrogen oxides. The other high-priority program is attempting to develop a power system for motor vehicles that is lower in emissions. This program aims at developing an unconventional vehicle and demonstrating its commercial feasibility by 1975. The EPA is also engaged in a massive air monitoring effort. Air monitoring is one of the areas in which the EPA is cooperating with state and local agencies.

Primary responsibility for air pollution control, except for new motor vehicles and interstate problems, rests with the states. State control programs have improved and increased in recent years in part due to the federal matching grants program. It is not encouraging, however, to note that, of the 55 state and territorial programs being financed by grants in 1970, only six have reached an annual per capita expenditure of 25 cents—generally considered a minimum needed for state programs. Less than half of the states are spending as much as 10 cents per capita per year. At the local level, approximately 44% of the 144 agencies that have received federal funding are spending at least 40 cents per capita per year. This is considered to be the minimum needed at the local level.

Another important problem in air pollution control is that of well-trained manpower. Half of the state agencies have fewer than 10 positions budgeted. It is estimated that by 1974 state and local agencies will need 8000 personnel to implement the Clean Air Acts properly. This is an increase of 300% or three times as many persons as were employed in

these programs in 1970. Many of the state and local agencies have minimal salary levels; this is causing difficulty in hiring new personnel. The 1970 HEW report to Congress, *Manpower and Training Needs for Air Pollution Control,* indicates that state and local median salaries fall 20% to 50% below those paid by industry for comparable positions.

The 1970 amendments to the 1967 Clean Air Act emphasized control of air pollution on the state and local level. Instead of trying to legislate from a national level, the EPA now controls or has absorbed most agencies and has formed state and local air pollution authorities. By January 31, 1972 these local groups or authorities had combined and developed a state plan that was submitted to the EPA. The EPA ruled on the state plan of implementation by June 30, 1972.

It should be noted that there is a mass network of governmental agencies dealing with air quality and enforcement of regulations they have set up. A person should be aware that they do exist and where he as an individual can go to get information helpful to him. These agencies are constantly changing to become more efficient regarding their assigned duties.

POTENTIAL FOR PROGRESS

Considerable data have been collected on air pollution and associated health problems. Unfortunately, even as the dangers to health from air pollution are being pointed out, improving air quality is not keeping pace with the increasing population, urbanization, and industrialization.

The costs of controlling air pollution are not nearly so high as those required to control water pollution. Stationary sources of air pollution can quite readily be controlled when technology is available. Research into the areas that we need to know more about should make for rapid progress in the future in controlling pollution.

Since the health problems connected with air pollution are important, they should receive high priority. Consideration should also be given to the fact that important improvements in air quality can be made at relatively low costs. There is little doubt that the benefits of overcoming air pollution far exceed the costs of controlling it.

SUMMARY

The following 15 recommendations were taken from *Environmental Quality: The First Annual Report of the Council on Environmental Quality.*

1. The President's legislative program should be enacted to deal more effectively with stationary sources by setting national air quality standards and national emission standards on substances harmful to health, by streamlining enforcement procedures, and by providing fines of up to $10,000 a day.

2. If the President's legislative program is enacted, the major Federal efforts on stationary sources should be directed toward the prompt establishment of national air quality standards covering a wide range of pollutants and toward development of emission control limits for harmful pollutants such as asbestos, beryllium, cadmium, and other toxic materials.

3. Programs must be developed to improve State and local control agencies.

4. Federal research and development on sulfur oxides and nitrogen oxide control technology should be accelerated.

5. A more balanced research and development program is necessary to hasten the development of more efficient energy processes.

6. Incentives to accelerate industry support for research and to stimulate corrective actions should be considered.

7. The President's legislative proposals for regulating fuel and fuel additives, taxing lead to be used in gasoline, and testing emission systems on the production line are critical for meeting motor vehicle emission standards and should be enacted.

8. Alternatives availabble to ensure continued control of motor vehicle emissions under actual road conditions should be evaluated.

9. The development and widespread testing of an inexpensive and effective emission control system for installation on used cars should be accelerated. Consideration should be given to requiring its use on all automobiles or on vehicles in areas with severe pollution problems.

10. The program for development of an unconventional vehicle propulsion system (e.g., steam, gas turbine, or hybrid) should be accelerated to ensure that the technology will be available if conventional propulsion systems are incapable of meeting increasingly stringent Federal standards.

11. Increased research should be conducted on the development of transportation systems that not only move people and goods efficiently, but also help reduce both dependency on the private car and, with it, air pollution.

12. More research should be conducted on the effects of air pollutants on man.

13. Federal, State, and local monitoring programs must be improved considerably.

14. Land use planning and control should be used by State, local, and regional agencies as a method of minimizing air pollution.

15. The United States should work toward cooperative arrangements with other nations in limiting total amounts of air pollutants emitted into the atmosphere.

You as an individual can help by checking:

Your car

- Have carburetor adjustment checked periodically.
- Replace faulty carburetor and fuel pump gaskets.
- Check distributor and spark advance mechanism.
- Be sure fuel tank filler cap gaskets fit tightly.
- Be sure your motor is not burning excessive oil.
- Change oil and filter cartridge regularly.
- Have spark gaps and spark plugs checked.
- Avoid gunning motor while idling.
- Purchase a blowing device for your car.
- Specify air pollution modifiers for a new car.

Your home

- Collect rubbish, dirt, and waste materials for pickup—don't burn.
- Clean furnace flues and the chimney.
- Never burn garbage or any other putrescible material.

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